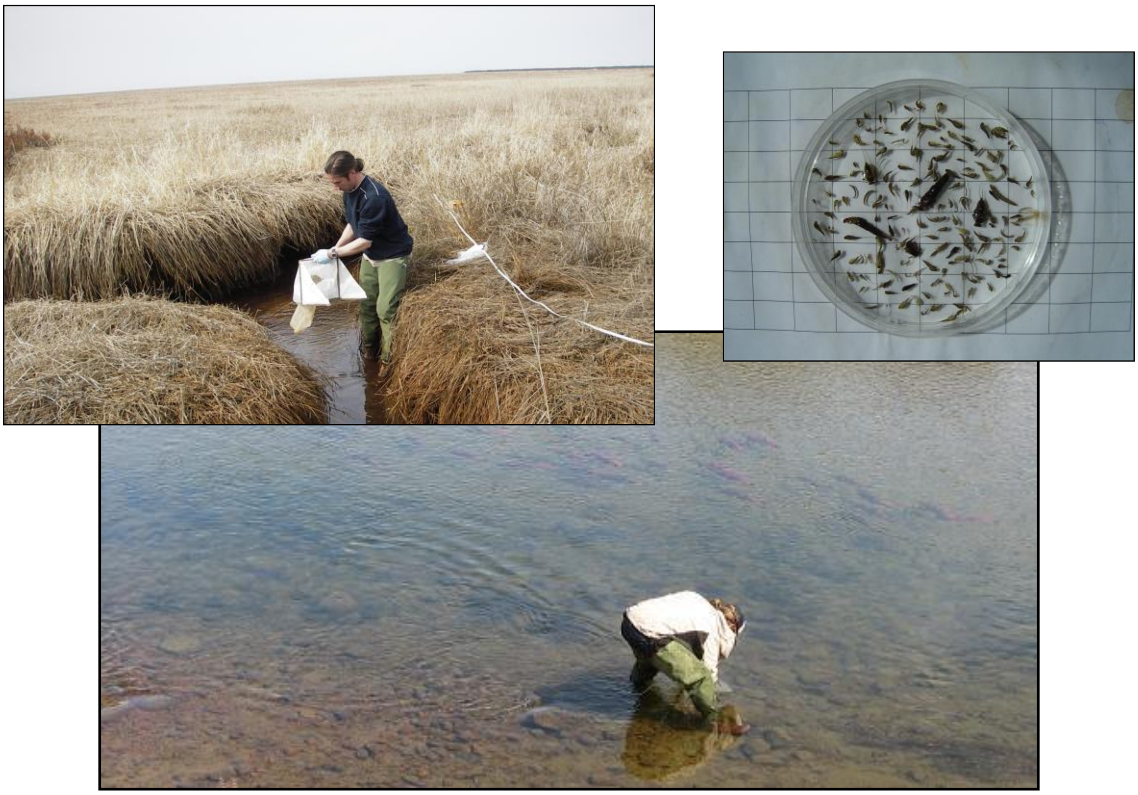
Pré-étude d'inventaire des macroinvertébrés aquatiques dans la Péninsule d'Alaska et une étude de l'effet d'un gradient environnemental sur la composition des communautés à King Salmon

-Pilot study of aquatic macroinvertebrates inventory in the Alaska Peninsula and an examination of an environmental gradient effect on the communauties assemblage in King Salmon-



Dans le cadre du Master 2 d'Ecologie Spécialité Gestion de la Biodiversité
Université Paul Sabatier, Toulouse, France

- Septembre 2007-

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Structure d'accueil: Alaska Peninsula and Becharof National Wildlife Refuge

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ACKNOWLEDGMENTS

I would like to thank first wildlife biologist Susan Savage to have get me the opportunity to realize my internship in Alaska, despite all the difficulty to get a visa. And for having show me what is rigor in science as well as having been an example in field work preparation.
I have to thanks biotechnician Sean Clawson for his help in insect identification at the beginning of my work as well as wildlife biologist Dominique "Wolf" Watts for his precious help in statistics even if he may think this was nothing.

I extend a special thanks to the personnel at the Alaska Peninsula and Becharof National Wildlife Refuge for their patience with me, especially Mark Koepsel as I was not familiar with firearm training. Thanks for pilot Dave Cox without who I would not have seen so much from Alaska and refuge manager Daryle Lons to lead this refuge always in a good mood. I would not forget administrative intender Kirstein Aiko for his very good intendance of this refuge and for her support in French.

To biotechnician Shawn Hawks I owe special thanks in showing me what looks like science through all his work, having invaluable feedback throughout the redaction of this report and being a high-level player in table soccer.

This project could not have been possible without the Fisheries Service (King Salmon Fish and Wildlife Field Office) which allows me to use their equipment for insect identification and the Alaska Department of Fish and Game of King Salmon from which I got ethanol in an effective manner. Specials thanks also to Dr. Derek Sikes for providing substantial input in the preparation of the field work.

As advisors I would like to thank Jean Joachim as well as Magalie Gerino for their disponibility through mail correspondence and their help in developing problematic.

I thank my brother for his "logistics support" from France to provide me some supplies and help me in my correspondence with administration services.

And finally, I would like to thank all the Alaska macroinvertebrate involved in this project for giving their lives in the spirit of science and the pursuit of knowledge.

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I. INTRODUCTION

The mission of the National Wildlife Refuge System is to administer a national network of lands and waters for the conservation, management, and, where appropriate, restoration of the fish, wildlife, and plant resources and their habitat for the continuing benefit of the American people (National Wildlife Refuge System Improvement Act, Public Law 105–57—Oct. 9, 1997). The Alaska National Interest Land Conservation Act (ANILCA) established the 3.7 million acre (1.5 million hectare) Alaska Peninsula National Wildlife Refuge and the 1.2 million acre (0.5 million hectare) Becharof National Wildlife Refuge on December 2, 1980. Prior to ANILCA, the lands were part of the federal public domain. In 1983, the Fish and Wildlife Service decided to manage the Ugashik and Chignik units of the Alaska Peninsula National Wildlife Refuge, the Becharof Refuge, and the Seal Cape area of the Alaska Maritime National Wildlife Refuge as one unit because they shared similar resources and common issues. Throughout this document the Becharof and Alaska Peninsula Refuges will be referred to in the singular as the "Refuge". Approximately 2,000 local residents live in 12 villages within or immediately adjacent to the Refuge. The refuge is open to the public and offers a variety of recreational opportunities, such as: hunting, fishing, hiking, and wildlife viewing (Final Comprehensive Conservation Plan).
The administrative office is supported by 10 permanent staff and is headquartered in King Salmon, at about 300 air miles southwest of Anchorage. The northern boundary of the Refuge is approximately 10 miles south of King Salmon.

1. Mission Purpose of the Refuge

The mission of this refuge, and many others, is to preserve and maintain ecosystems in their original state, allowing for natural processes to continue with minimal disturbance. The purposes outlined from the 2006 Revised Comprehensive Conservation Plan for which the Alaska Peninsula and Becharof National Wildlife Refuge is established and shall be managed include:

i. to conserve wildlife populations and habitats in their natural diversity including, but not limited to, brown bears, salmon, migratory birds, the Alaska Peninsula caribou herd, and marine mammals and birds;
ii. to fulfill the international treaty obligations of the United States concerning wildlife and their habitats;
iii. to provide, in a manner consistent with the purposes set forth in subparagraphs (i) and (ii), the opportunity for subsistence uses by local residents;
iv. to ensure, to the maximum extent practicable and in a manner consistent with the purposes set forth in paragraph (i), water quality and necessary water quantity within the refuge.

2. General Study Area

The Alaska Peninsula is located on a remote western portion of the North American land mass that extends far into the North Pacific for about 500 miles long and leads to the Aleutian Islands chain (Talbot *et al*., 2006). The Alaska Peninsula/ Becharof National Wildlife Refuge is a continuum of undisturbed sub-arctic ecosystems stretching throughout most of the Alaska Peninsula (Fig. 1). The refuge complex is approximately 4,200,000 acres (=1,700,000 Ha) consisting of a mosaic of active volcanoes, broad valleys, tundra, fjords, and glacially formed lakes. The Bristol Bay side of the Refuge consists primarily of tundra, lakes and wetlands. From this low coastal plain, the land rises to glaciated mountains above 1500m that stretch along the eastern length of the Peninsula nearer the Pacific Ocean. The Pacific side is irregular, with abrupt cliffs and sandy beaches. (REFERENCE?)

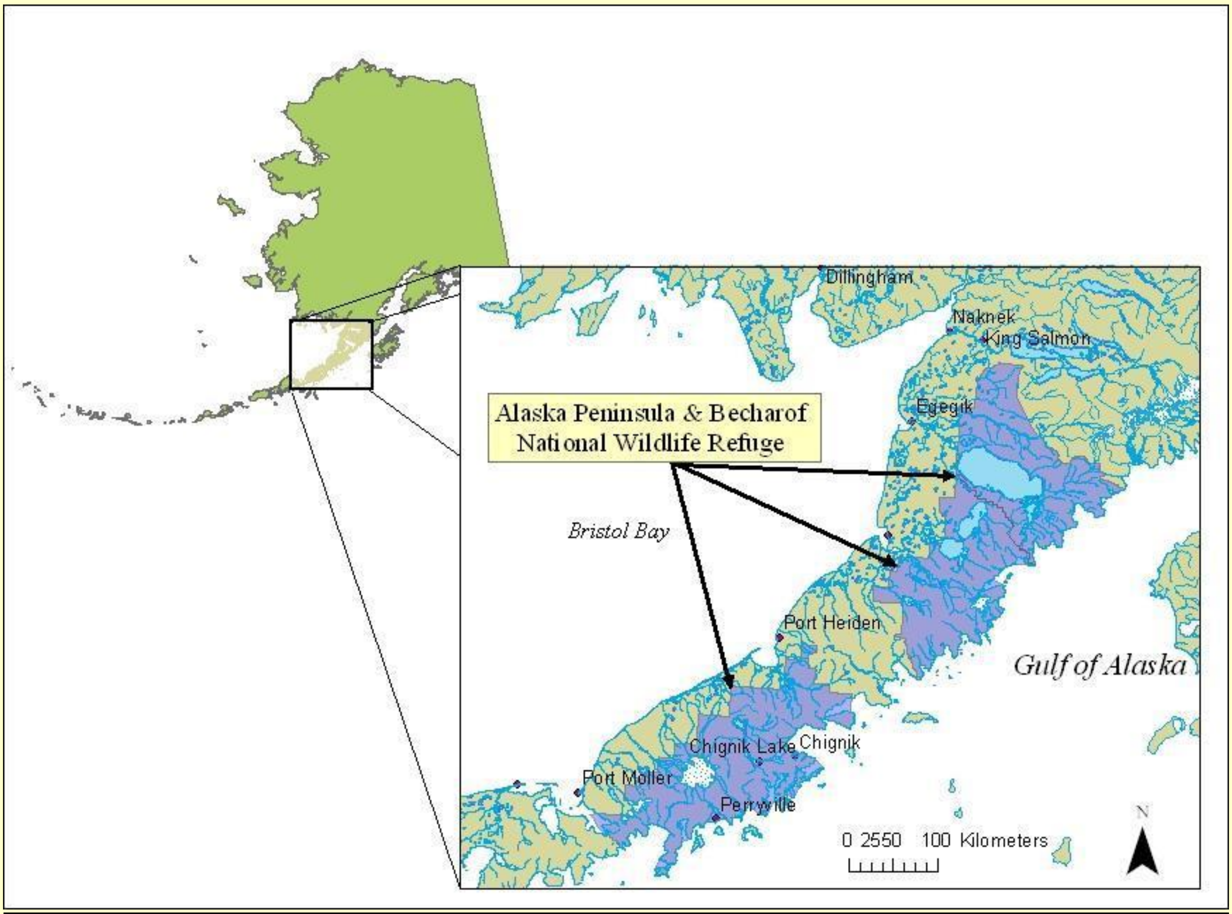

Fig. 1: Location of Alaska Peninsula and Becharof National Wildlife Refuge
(source: Garmin MapSource©)

II AQUATIC MACROINVERTEBRATES INVENTORY IN THE ALASKA PENINSULA: A PILOT STUDY

1. Background:

Macro invertebrates are key players in the ecosystems of lakes and streams. They are the main food for fishes and aquatic birds, so that the abundance and diversity of macro invertebrate populations are essential components of healthy aquatic

ecosystems (Gabrielson, 1993). The richness of macroinvertebrates fauna present in a stream is an indicator of water quality (Milner and Oswood, 1990).
In a consequence obtaining data on biodiversity and relative abundance of these invertebrates can help resources managers in preserving and promoting wise use of lotic ecosystems. Fishes and birds linked to aquatic habitats would seem ideal as biological indicators since these are the organisms of concern as game animals, as watchable wildlife, and often as endangered or threatened species emblematic of whole communities (Oswood *et al*., 2004). However, fishes and especially birds are highly mobile, moving among systems in seasonal migrations and are able to escape local lapses in water quality. Benthic macroinvertebrates and mostly aquatic insects have several advantages as bioassessment tools: most benthic macroinvertebrates are relatively long-lived (generation times from months to years), have low mobility so that they act as continuous monitors of water and habitat quality, and react strongly and often predictably to human influences on aquatic systems (Cairns and Pratt, 1993). Many species of Chironomids and Tubicid worms are considered pollution tolerant in a stream (Merrits and Cummins, 1994), whereas the macroinvertebrates orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies), termed EPT, are often listed as bioindicator organisms for freshwater bioassessment as most taxa in these three orders are considered sensitive to water quality impairment (Karr *et al*., 1986; Love, 1999).
For the purpose of this assessment, a taxonomic group or taxon will represent any group whose physical characteristics readily distinguish it from all others groups.

Unlike the 48 lower States, wildlife conservation in Alaska consists more in inventorying habitats, preventing human impacts and preserving pristine ecosystems than in manipulation activities like habitat restoration or species reintroduction actions. To assess presence, relative abundance, distribution, and trends in populations of wildlife, and plants, the Refuge has implemented in 2007 a pilot study to investigate the feasibility of a wildlife resources inventory and monitoring project over the entire Refuge. The goal is to develop a grid of plots to be surveyed over the next five years. Components to be surveyed include birds, plants, terrestrial insects, and other vegetation.
Located outside the road system the Refuge is accessible only by aircraft. The size, remoteness, and the diversity of the Refuge complex, along with weather, make it very challenging to collect data on species and require large amounts of logistical planning which increase costs significantly.
In agreement with Wildlife Biologist Susan Savage while completing inventory and monitoring projects, it has been proposed to include aquatic macro invertebrates as no data collect has been documented in the area. Therefore from May to August 2007 through several projects a qualitative benthic macroinvertebrates sampling has been accomplished to provide information about the taxonomic richness present in streams on the Alaska Peninsula. Pending the results of this pilot study, aquatic macro invertebrates might be proposed to be incorporated in the Refuge Wildlife Inventory

and Monitoring scheme since this protocol met both ANILCA purposes and the Biological Integrity, Diversity and Environmental Health Policy (BIDEH) Policy 2001. One of the Refuge Goals is indeed to improve baseline understanding of Refuge lakes and streams following the schedule identified in the water resources investigation plan (?). The aim is to acquire and maintain the water quality and quantity necessary to conserve fish and wildlife populations and habitats in their natural diversity within or near the Refuge (Goal 4 in Revised Comprehensive Conservation Plan).

a. Study Objectives:

- Develop sampling protocol for aquatic macroinvertebrates in 2007,
- Obtain baseline data to provide background information of the macroinvertebrates families that are represented on the Alaska Peninsula,
- Increase baseline samples of aquatic invertebrates of the Museum of the North located at the University of Alaska, Fairbanks.

The goal of this study, if extended in the future, is to get an inventory of macroinvertebrates from all types of stream habitat (varying) in size and in substrate materials. The designated objectives might help to increase understanding of streams ecology on the Refuge, and their ability to manage important fish populations.
These data could also provide valuable information for responding to long or medium-term changes in biodiversity-patterns as it would occur with local development, with a climate change(,) or after catastrophic events like a volcanic eruption since the major disturbance regime within the Refuge is volcanic activity. So just think about it, since volcanism is a natural disturbance, what kind of management response would be warranted…? In this purpose it is necessary to have reference standards against which to compare the data. Due to time and effort limit, the inventory conducted this year was restricted to streams and does not include ponds.
Macroinvertebrates were identified at a family level or, in some cases (Oligochaeta -aquatic worms-, Unionoida -freshwater mussels-, Arachnida and Crustacea), at an order level. A more precise level was not allowed due to lens power limitation of the microscope accessible and time limit for identification. However there are different schools of though on which levels of identification are necessary. In Alaska, individuals collected are often immature and difficult to identify. Additionally, these are few identification guides specific to this region. These factors warranted identification to the family level for this project. Taxonomic was identified using Bouchard (2004) and Thorp and Covich (1991).

The protocol used is based on the stream sampling protocol outlined by the "Kanuti National Wildlife Refuge Final Report FY01-01". The purpose of that report was to provide (a) standardized sampling method for a statewide approach to biological monitoring (Oswood *et al.*, 2004).
A Scientific Collecting Permit that specifies the taking of freshwater invertebrates from the waters of the state was obtained from the Alaska Department of Fish and Game

prior to conducting this study and sampling equipment has followed decontamination practices as described in the Permit.

b. Study area:

Fourteen streams were chosen for macroinvertebrates sampling along the Alaska Peninsula (Table 1). Some of them are not within the Refuge boundaries (Fig. 2). A total of 120 hours has been produced (expended) to provide this collection, with the time being equally divided among field sampling and identification. Both have been conducted by the primary author. The sample collect has start in late spring (15 May) to finish in late summer (29 August). The collecting period began in late spring (15 May) and ended in late summer (29August).Streams typically have low diversity of macroinvertebrates in midsummer because many taxa mature and grow during the warm waters of summer, so that mature larvae and adults (necessary for identification) are most abundant in late spring or late summer (Oswood *et al*., 2004). Thus, theses periods are the optimum time period for collecting the maximum number of macroinvertebrates taxa that the stream station can support providing the most accurate results for the metrics calculated (Milner and Oswood, 1990). I don't get your logic.

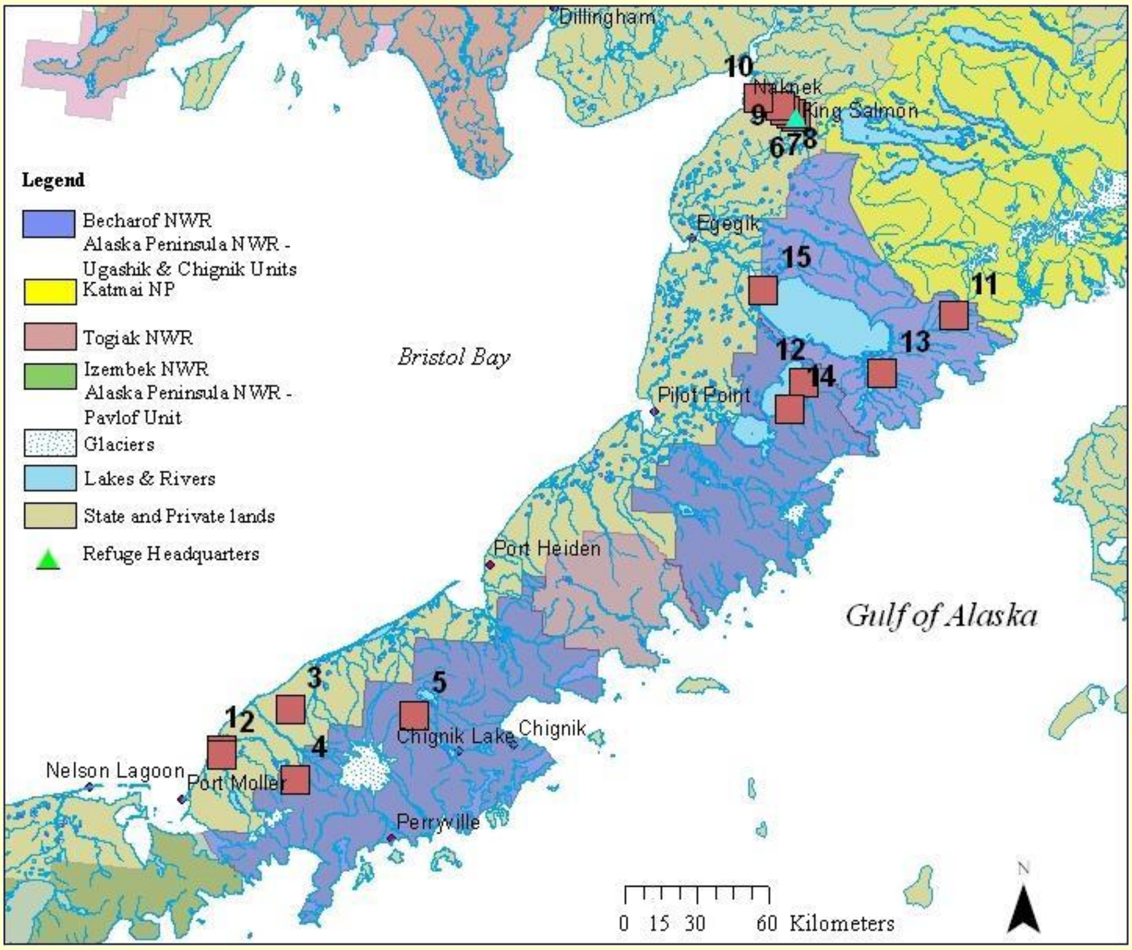

Fig. 2: Location of the 14 macroinvertebrate sampling sites* in the Alaska Peninsula and Becharof Refuge areas (source: Garmin MapSource®)

* Sites 1 and 2: Sandy River; 3: Bear River; 4: Muddy River; 5: Chignik River; 6: Eskimo Creek; 7: King Salmon Creek; 8: Paul's Creek; 9: Memorial Creek; 10: Leader Creek; 11: Kegulik KejulikRiver; 12: Ugashik River; 13: Cleo Creek; 14: Deer Creek; 15: Egegik River.

Sampled Stream	Flow Velocity [m/s]	Width [m]	Latitude**	Longitude**	Dominant Substrate	Sample Date
Sandy River 1	medium (0.5)	40	N 56.23363	W 160.22040	rocky-muddy	15-May-2007
Bear River	fast (4)	1	N 56.17325	W 160.33533	muddy	19-May-2007
Muddy River	medium (0.5)	5	N 56.36357	W 159.90927	rocky	20-May-2007
Sandy River 2	medium (0.5)	20	N56.104754	W 159.83379	rocky	21-May-2007
Chignik River 1	medium (0.5)	2	N 56.37911	W 159.07152	rocky	23-May-2007
Chignik River 2	fast (1)	30	N 56.37884	W 159.07071	rocky	24-May-2007
Kegulik River	fast (1)	4	N 57.96457	W 155.50269	rocky-sandy	13-Jun-2007
Ugashik River	fast (1)	20	N 57.70303	W 156.54193	rocky-sandy	14-Jun-2007
Cleo Creek	medium (0.5)	20	N 57.74348	W 155.99254	rocky-sandy	29-Jun-2007
Deer Creek	medium (0.5)	20	N 57.60208	W 156.63190	rocky	9-Aug-2007
Egegik River	fast (1)	40	N 58.04028	W 156.84683	rocky-sandy	13-Aug-2007
Eskimo Creek 1	fast (1)	2	N 58.68557	W 156.66978	rocky	10-Jun-2007
King Salmon Creek 1	medium (0.5)	30	N 58.69765	W 156.69556	rocky	10-Jun-2007
Memorial Creek 1	medium (0.5)	1	N 58.71099	W 156.74239	muddy-sandy	18-Jun-2007
Paul's Creek 1	medium (0.5)	25	N 58.72380	W 156.77991	rocky-muddy	11-Jun-2007
Leader Creek 1	medium (0.5)	1	N 58.74910	W 156.94374	rocky-muddy	19-Jun-2007
Eskimo Creek 2	fast (1)	2	N 58.69129	W 156.66550	rocky	19-Jul-2007
King Salmon Creek 2	fast (1)	30	N 58.69765	W 156.69556	rocky	20-Jul-2007
Memorial Creek 2	medium (0.5)	1	N 58.70991	W 156.74416	muddy	21-Jul-2007
Paul's Creek 2	slow (0.2)	25	N 58.72360	W 156.77963	muddy	22-Jul-2007
Leader Creek 2	medium (0.5)	1	N 58.74910	W 156.94373	rocky	23-Jul-2007
Eskimo Creek 3	fast (2)	2	N 58.69156	W 156.66536	rocky	27-Aug-2007
King Salmon Creek 3	fast (2)	30	N 58.69717	W 156.69661	rocky	27-Aug-2007
Memorial Creek 3	medium (0.5)	1	N 58.71114	W 156.74293	muddy	28-Aug-2007
Paul's Creek 3	medium (0.5)	25	N 58.72424	W 156.78078	rocky-muddy	29-Aug-2007
Leader Creek 3	medium	1	N 58.74878	W 156.94362	rocky-	29-Aug-2007

(0.5) sandy

Table 1: Locations sampled on the Alaska Peninsula, May-August 2007
** Coordinate Datum: NAD 83; unit: decimal degrees

Outside the ones surrounding the King Salmon area the locations situated along the Peninsula correspond to plots semi-randomly chose (based on a randomized sampling scheme then selected for their accessibility and the nature of the cover). These plots have been visited during the spring and the summer to complete the different inventory and monitoring programs in progress (landbirds, ~~shorebirds,~~ vegetation, insects). At the very beginning of the study, the method have been based on sampling only one single habitat in a stream reach (single station sites): in consequence, Bear River and Muddy River are represented by one single sample while Chignik River is represented with two of them collected in two different parts of the river. For every station afterwards five samples have been located (multi-station sites). Six samples have been collected in Sandy River due to one first single sampling (Sandy 1)following by a set of five samples (Sandy 2).

For the locations in the local area of King Salmon (Eskimo Creek, King Salmon Creek, Memorial Creek, Paul's Creek and Leader Creek), the sampling have been conducted three times during the season in (for) the purpose of a semi-quantitative survey as explained in the second part of the report. Therefore theses stations are represented by 15 samples.

2. Methods:

a. Sampling methodology:

A "sampleable" area within fast water habitat shallow enough to allow safe wading (≤1 m) was selected at each site after a rapid prospecting. The general guidelines are 0.5 meter to separate shallow from deep, and 0.3 meter/sec to separate fast from slow (Major *et al*., 1998).
A 30m reach of stream was measured starting with the first rapid encountered. Five random macroinvertebrates samples (duplicates) were collected from the bottom of the stream using a Surber sampler with a 980 micron mesh net onto the substrate (Fig. 2). The 0.09 m^2 ($1ft^2$) area was excavated to an approximate depth of 10-15 cm (4-6 in) when possible. In situations where the area was dominated by boulder substrates too large to move or when the depth was too important, the net was placed at the more suitable adjacent portion of the sampling location. Collecting was then repeated by proceeding upstream. A consistent sampling effort (approximately 2-3 minutes) was maintained at each location. Samples were then collected using an aspirator, preserved in Whirl-Pak bags with 95% ethanol and subsequently sorted in the laboratory by using 40X stereo-microscope.

For each sampling site, substrate type and water depth were recorded. GPS coordinates (Downloaded using DNRGarmin…Reference…) stream width and current velocity at the bottom of the reach and some other information as water temperature, current velocity, turbidity, pH and specific conductance at the center (of the transect?) were also recorded. It should be is worth noting that this survey has been limited by weather when skies are not raining as samples from surface could differ.

The collected specimens are at present housed in the collection of entomology of the Museum of the North, Fairbanks, which is the regional archive for zoological collections. (This is misleading. The specimens are still at USFWS which will have to pay for their identification at the Museum). An external review is going to be performed as quality control procedure by Dr. Sikes, curator of Entomology Collection. Unfortunately these results are not available at the time of completing this report. It is assumed that the sorting errors which could have occurred in the lab do not affect the final conclusions presented in this report.

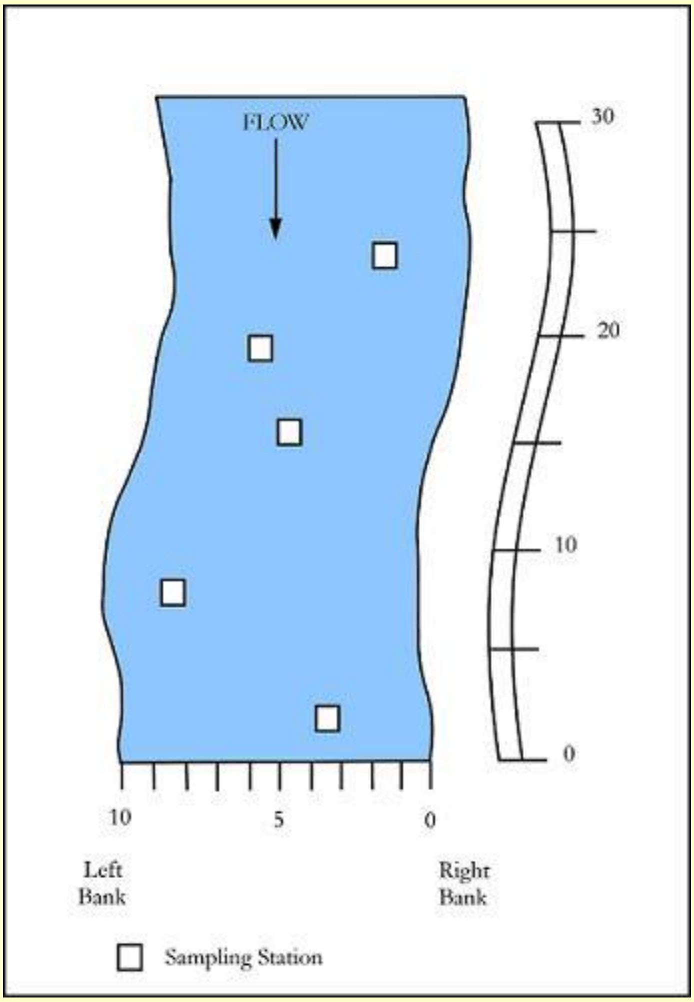

Fig. 3: Representation of a sampling grid for a 10m wide stream
Ex: The first sample would be taken with the random coordinates 23, 1.
(from an illustration in Oswood *et al*., 2004)

b. Statistical analysis:

A metric is a characteristic of the biota that changes in some predictable way with increasal human influence (Barbour et al., 1995; Love, 1999). Eight metrics, based on richness or composition, were considered in this study to compare the stations (to) each other. All the metrics are based upon family-level (you said some only IDed to Order) identification. Taxa richness, defined as the number of families identified, and abundances have been determinate to measure the overall variety of the macroinvertebrate assemblage. The EPT (ACRONYM NOT DEFINED) to total individuals ratio reflects a higher water quality as this value increases towards a maximum of 1.

Jaccard's Coefficient of Community Index (Plafkin et al., 1989; Love, 1995) scores were calculated to quantitatively estimate similarity between all samples. This method measures the similarity in taxonomic composition and is based on presence or absence of taxa in a sample. Coefficient values range from 0 to 1, with 0 representing no similarity between the two sites, and 1 representing complete similarity between the two sites. Scores were calculated for each site according to the following equation:

Jaccard's Coefficient = A/ (A+B+C) where

A = number of taxa common between both samples;

B = number of taxa found in B but not in A; and

C = number of taxa found in A but not in B.

Jaccard's coefficients were calculated for each site in comparison with all other sites.

Pollution Tolerance Index (PTI) has also been calculated. This index measures the relative sensitivity of different groups to pollution. Each group is assigned to one of the Pollution Tolerance Levels enclosed in Appendix 1. Each level has numeric pollution index value. The number of different taxonomic groups are multiplied by the pollution index value for each level (3, 2, or 1) and added together as shown below to obtain the PTI.

PTI = (# of "Level 1" taxa X 1) + (# of "Level 2" taxa X 2) + (# of "Level 3" taxa X 3)

For each sampling site located in the King Salmon area the numbers of each taxa per station given is an average of the three samples. (I know you didn't write this section, where is your reference?)

A multivariate analysis using the statistics software Minitab®, version 15.0, has been performed in order to observe variation in community composition with several environmental variables simultaneously (pH, conductivity, flow velocity, water temperature, stream width, nature of substrate).

Correlation test between different taxa distributions have been performed using the Spearman rank-order test to ascertain if correlations were significant. Probability (P) values of less than 0.05 were considered significant. In most field work we consider $P < 0.10$ significant because the 0.05 level is pretty hard to achieve in natural settings. The hypothesis H0 were: $\varrho = 0$ versus H1: $\varrho \neq 0$ where ϱ is the correlation between the pair of variables.

The repartition of aquatic invertebrates in King Salmon and in the Refuge area has also been statistically analyzed at a family level by applying the same test.

3. Results:

Fourteen different streams have been sample for a total of 110 samples.
A total of 1722 specimens representatives of (representing) twenty families was observed. (macroinvertebrates families present in samples collected are summarized for each stream in Appendix 2). Eleven different orders and six different classes are represented (Tables 2 and 3). This collection shows as well a relative considerable variability abundance with the number of individuals for each station ranging from a low of 5 at Ugashik River to a high of 458 at Sandy River (Sandy 1 or 2?). Even though taking into account only the five first samples (since there was one more sample collected) the greatest number of individuals is still occurring in Sandy River. Sentence is unclear.

Class	Order	Sandy	Bear R	Muddy	Chigni	Keguli	Ugashi	Cleo C	Deer C	Egegik
Insecta	Ephemeroptera	140	0	0	1	1	44	6	0	0
Insecta	Plecoptera	26	0	5	4	89	1	2	0	1
Insecta	Trichoptera	0	0	0	0	1	0	4	13	0
Insecta	Diptera	256	38	0	38	11	4	59	4	44
Insecta	Coleoptera	0	0	0	0	0	0	0	0	0
Oligochaeta	Tubificida	0	7	3	1	2	0	4	6	1
Unionoida	Unionidae	0	0	0	0	0	0	0	0	0
Arachnida	Araneae	0	0	0	0	0	0	0	0	0
Crustacea	Isopoda	0	0	0	0	0	0	0	0	0
Gastropoda	Neotaenioglossa	0	0	0	0	0	0	0	0	0
Gastropoda	Ectobranchia	0	0	0	0	0	0	0	0	0
	Total individuals	422	45	8	44	104	49	75	23	46

Table 2: Taxa and abundance for each station outside the local area of King Salmon

Class	Order	Eskimo Cre	King Salmo	Memorial C	Paul's Cre	Leader Cre	Eskimo Cre	King Salmo	Memorial C	Paul's Cre	Leader Cre	Eskimo Cre	King Salmo	Memorial C	Paul's Cre	Leader Cre

		ek 1	n Creek 1	reek 1	ek 1	ek 1	ek 2	n Creek 2	reek 2	ek 2	ek 2	ek 3	n Creek 3	reek 3	ek 3	ek 3
Insecta	Ephemeroptera	12	12	0	4	0	2	5	1	0	0	0	0	0	0	1
Insecta	Plecoptera	15	3	1	2	6	7	5	0	0	3	2	0	0	0	0
Insecta	Trichoptera	1	4	0	3	1	1	38	7	0	6	30	145	0	2	1
Insecta	Diptera	2	5	8	15	22	5	10	9	6	15	1	4	2	12	35
Insecta	Coleoptera	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	Tubificida	0	4	3	44	83	0	9	22	11	131	1	1	6	98	21
Unionoida	Unionidae	0	3	0	0	0	0	0	0	0	1	0	1	0	2	0
Arachnida	Araneae	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0
Crustacea	Isopoda	0	0	0	1	0	0	0	0	0	0	0	0	0	25	0
Gastropoda	Neotaenioglossa	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0
Gastropoda	Ectobranchia	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
	Total individuals	31	31	14	70	112	15	68	39	17	156	36	151	8	144	58

Table 3: Taxa and abundance for each station in the local area of King Salmon

The percentage of unidentified taxa at a family level is 28.3% (n=487) but this proportion is due to the Chironomids (26.6%, n=458) since the Chironomidae larvae are primarily identified by their mouthparts and a positive identification requires examination under microscope (Major *et al.*, 1998). Dipterans were the most abundant order, accounting for 602 specimens (35.0%), followed by Tubificida (26.6%; n=458), Trichoptera (14.9%; n=257), Ephemeroptera (10.9%; n=187), and Plecotera order (10.0%; n=172). The others orders represented less than 2% of the total: Isopoda (n=26), Unionidae (n=7), Araneae (n=4), Neotaenioglossa (n=4), Ectobranchia (n=2) and Coleoptera (n=2). Lepidopterans are present in the collect by one single specimen. In total the class of Insect count for 69.9% (n=1219) of the specimens collected while the Oligochaeta class (n=458) represents 26.6% of the total. The unidentified taxa at an order level represent 2.3% (n=40) of the total and is compound (composed) of Insect pupae. The unidentified taxa at a family level collected in the local area of King Salmon (Eskimo Creek, King Salmon Creek, Memorial Creek, Paul's Creek and Leader Creek) accounted for 98.97% (n=482) of the unidentified taxa while those unidentified at an order level are located for 99.6% in the sampling sites in and around the Refuge. In terms of presence the most abundant order (Ephemeroptera, Plecoptera, Trichoptera, Diptera, and Tubicifida) are naturally also the most common (Table 4).

	Number of sites	Number of individuals	Average per site	Standard deviation	Range	Location of maximum range
Ephemeroptera	10	187	21	41	1-140	Sandy River
Plecoptera	10	172	14	26	1-89	Kegulik River

Trichoptera	8	257	6	4	1-145	King Salmon Creek
Diptera	12	603	38	68	1-256	Sandy River
Coleoptera	2	2	1	0	1-1	Memorial Creek
Lepidoptera	1	1	1	0	1-1	Eskimo Creek
Tubificida	11	458	12	16	1-131	Leader Creek
Unionidae	3	7	2	1	1-3	King Salmon Creek
Araneae	4	4	1	0	1-1	Eskimo, Memorial and Paul's Creek
Isopoda	2	26	13	12	1-25	Paul's Creek
Neotaenioglossa	2	4	2	1	1-3	Paul's Creek
Ectobranchia	1	2	2	0	2-2	Paul's Creek

Table 4: Abundance of the different orders within the sampling sites

The Tricoptera order presents the lowest standard deviation of all the orders examined. Isopoda are present in two singles sites but with a relatively large deviation standard due to the sample size in Paul's Creek. Only one family (Nemouridae) present in the Refuge area is absent in the samples collected around King Salmon while ten families (Heptageniidae, Hydropsychidae, Limnephilidae, Simuliidae, Ditiscidae, Psephenidae, Lepidotera, Unionidae, Aranea, Hydropbiidae, and Valvatidae) which have been identified in theses samples are not represented in the collection issued from the Refuge. Furthermore Simulids at a pupae level are present only in the Refuge area samples while Isopod adults and Simulids larvae are present only in the samples from the King Salmon area.

		Sandy	Bear R	Muddy	Chigni	Keguli	Ugashi	Cleo C	Deer C	Egegik
Insecta	Ephemeroptera	140	0	0	1	1	44	6	0	0
Insecta	Plecoptera	26	0	5	4	89	1	2	0	1
Insecta	Trichoptera	0	0	0	0	1	0	4	13	0
Insecta	Diptera	256	38	0	38	11	4	59	4	44
Insecta	Coleoptera	0	0	0	0	0	0	0	0	0
Insecta	Lepidoptera	0	0	0	0	0	0	0	0	0
Oligochaeta	Tubificida	0	7	3	1	2	0	4	6	1
Unionoida	Unionidae	0	0	0	0	0	0	0	0	0
Arachnida	Araneae	0	0	0	0	0	0	0	0	0
Crustacea	Isopoda	0	0	0	0	0	0	0	0	0
Gastropoda	Neotaenioglossa	0	0	0	0	0	0	0	0	0
Gastropoda	Ectobranchia	0	0	0	0	0	0	0	0	0

Table 5: Taxa and abundance for each station outside the local area of King Salmon

Class	Order	Eskimo Creek 1	King Salmon Creek 1	Memorial Creek 1	Paul's Creek 1	Leader Creek 1	Eskimo Creek 2	King Salmon Creek 2	Memorial Creek 2	Paul's Creek 2	Leader Creek 2	Eskimo Creek 3	King Salmon Creek 3	Memorial Creek 3	Paul's Creek 3	Leader Creek 3
Insecta	Ephemeroptera	12	12	0	4	0	2	5	1	0	0	0	0	0	0	1
Insecta	Plecoptera	15	3	1	2	6	7	5	0	0	3	2	0	0	0	0
Insecta	Trichoptera	1	4	0	3	1	1	38	7	0	6	30	145	0	2	1
Insecta	Diptera	2	5	8	15	22	5	10	9	6	15	1	4	2	12	35
Insecta	Coleoptera	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Insecta	Lepidoptera	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Oligochaeta	Tubificida	0	4	3	44	83	0	9	22	11	131	1	1	6	98	21
Unionoida	Unionidae	0	3	0	0	0	0	0	0	0	1	0	1	0	2	0
Arachnida	Araneae	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0
Crustacea	Isopoda	0	0	0	1	0	0	0	0	0	0	0	0	0	25	0
Gastropoda	Neotaenioglossa	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0
Gastropoda	Ectobranchia	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
	Total	31	31	14	70	112	15	68	39	17	156	37	151	8	144	58

Table 6: Taxa and abundance for each station in the local area of King Salmon

No order has been found in every stream of the Peninsula (Tables 5 and 6). The Diptera class is present in twelve out of the fourteen locations sampled while the Oligochaetes are represented in eleven locations. The others class (Arachnida, Unionoida, Gastropoda, and Crustacea) have been respectively found in 4, 3, 2, and 1 locations.

a. Metrics conclusions

Table 7 summarizes the biotic metrics calculated for each site. For each EPT order, a family is dominantly represented. The percentage of dominance within each order (individuals of the dominant family to individuals of the order) are the following: Ephemeroptera: 80.75% (n=187) with the Baetidae; Plecoptera: 81.40% (n=172) with the Chloroperlidae and Trichoptera: 69.65% (n=257) with the Glossosomatidae. The family diversity for Ephemeroptera (n=3) and Plecoptera (n=3) is relatively low among the samples collected. Six families belonging to the Trichoptera order are represented in the Alaska Peninsula. The taxa richness, defined as the number of families identified, range from 1 (Muddy River) to 9 (King Salmon Creek) with an average of 5 families per station (σ=2). The Dipterans group is mainly composed of Chironomids (midges) (68.99%; n=416). The Tipulidae family (crane flies) count for 14.76% (n=89) while the Simulids (black flies) are for 4.48% (n=27) of the total. For the EPT orders, Plecoptera is well represented in Muddy River, Kegulik River, Ugashik River while Trichoptera is more abundant in King Salmon Creek, Cleo Creek, and Deer Creek. Ephemeroptera order is only found in prevalent abundance in Sandy River.

	Total aquatic taxa	% Epheme-roptera	% Pleco-ptera	% Tricho-ptera	% EPT	% Chiro-nomi-dae	% Oligo-chaeta	% Misc. Aquatic species
Sandy River	458	30,6	5,7	-	36,2	48,9	-	7,9
Bear River	45	-	-	-	-	84,4	15,6	-
Muddy River	8	-	62,5	-	62,5	-	37,5	-
Chignik River	47	2,1	8,5	-	10,6	78,7	2,1	6,4
Eskimo Creek	84	18,6	32,6	31,0	82,2	13,1	0,9	3,8
King Salmon Creek	250	15,4	5,7	54,9	76,0	8,9	8,9	4,2
Paul's Creek	231	1,9	1,0	1,9	4,7	20,0	65,2	8,4
Memorial Creek	61	0,9	2,4	6,0	9,2	23,5	50,9	4,8
Leader Creek	326	0,6	2,4	2,2	5,2	1,2	64,8	0,2
Kegulik River	104	1,0	85,4	1,0	87,5	9,6	1,9	-
Ugashik River	5	-	20,0	-	20,0	-	-	-
Cleo Creek	75	8,0	5,3	16,0	16,0	78,7	5,3	-
Deer Creek	22	-	-	59,1	59,1	4,5	27,3	-
Egegik River	46	-	-	2,2	2,2	95,7	2,2	-

Table 7: Metrics results for all sampling sites in the Alaska Peninsula

~~It would be noted~~ (Note) that three streams –all located around King Salmon- (Paul's Creek, Memorial Creek and Leader Creek) present different patterns with a low proportion in EPT taxa and a high level of oligochaetes, signifying a depauperate invertebrate community. But the under-oxygenated condition of these streams as it appears do not mean necessarily that pollutants are damaging water quality : the absence of EPT abundance can also be explain by water velocity, water temperature or habitat degradation such as excess sand or silt on the stream bottom. (Paul's creek and Leader Creek, depending on where you sampled, also experience tidal fluctuations)

The Jaccard's Coefficients scores (see Appendix 3) show an average of 0,29 (σ=0,14) for the population in the Refuge area and an average of 0,41 (σ=0,08) for the King Salmon area: as expected in reason of their geographic proximity, the similarity within the King Salmon samples is stronger than the one within the Refuge samples. But the comparison between the two areas give an average of 0,34 (σ=0,17): populations collected in the streams around King Salmon are shown to be more similar to the streams of the rest of the Alaska Peninsula than theses streams between them.

Except for Sandy River (site 1) where the effective are important for Ephemeroptera, Plecoptera and Diptera orders, the other sites may present a single order in abundance but neither two (Fig. 4).

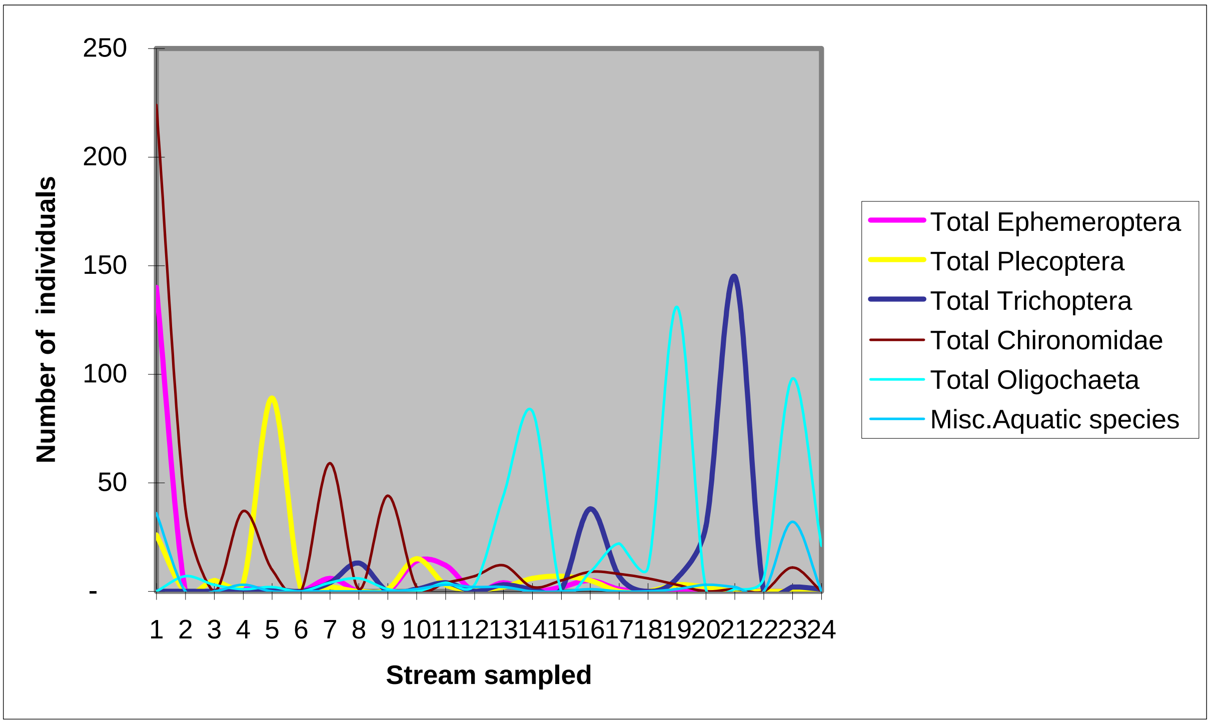

Fig. 4: Abundance of the different aquatic insect orders per site

As displayed in Figure 5, the relative abundance in EPT, Chironomids and Oligochaetes, allow defining four groups for the streams sampled:
- predominance of Plecopterans : Kegulik River, Muddy River, Ugashik River;
- predominance of Chironomids : Sandy River, Bear River, Chignik <clioathèque, Cleo Creek, Egegik River;
- predominance of Trichopterans : King Salmon Creek, Deer Creek;
- predominance of Oligochaetes : Paul's Creek, Memorial Creek, Leader Creek.

Eskimo Creek can not be include in one of these groups as it is compound (composed) of mainly ~~of~~ EPT in equal proportions.

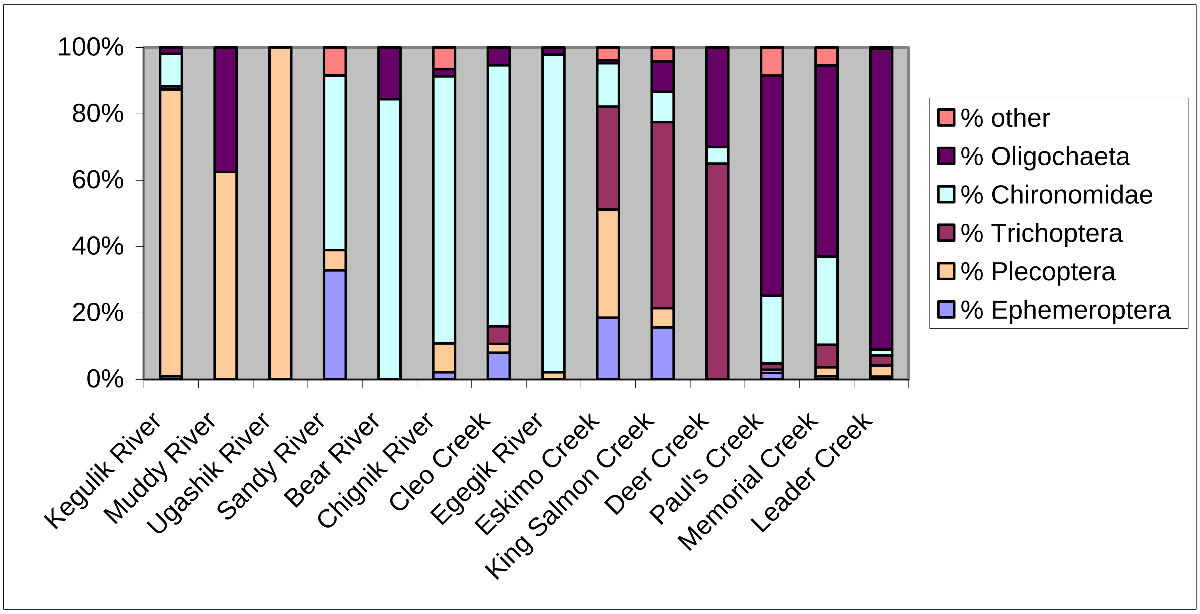

Fig. 5: Relative proportion of aquatic insect orders in the sampling population

Pollution Tolerance Index (Table 8) suggests that all stations except Sandy River, Kegulik River and King Salmon Creek have relative low impaired level but these indices are more powerful to compare sites with similar invertebrates abundance otherwise sites with number of individuals are more likely to appear impaired.

Sandy River	Bear River	Muddy River	Chignik River	Kegulik River	Ugashik River	Cleo Creek
754	45	18	54	286	139	99
Deer Creek	Egegik River	Eskimo Creek*	King Salmon Cr.*	Memorial Creek*	Paul's Creek*	Leader Creek*
49	48	29,33	257,33	27	94	84,67

Table 8: PTI Results for all sampling sites
(For the streams with an asterisk the value represents the average of the duplicates taken at three different periods)

b. Correlations

A Spearman correlation test conducted between the main taxa show no significant results. No significant differences ($p>0.05$) were found on the different comparisons. However, the probability value for a negative correlation between the Insects and the Oligochaetes distributions was close to 0.05 ($r(s) = -0.385$; probability (P) value = 0.063). This trend can be observed on an output that combines both distributions (Fig. 6). No other correlation with the Oligochaetes or between other classes have been significantly established.

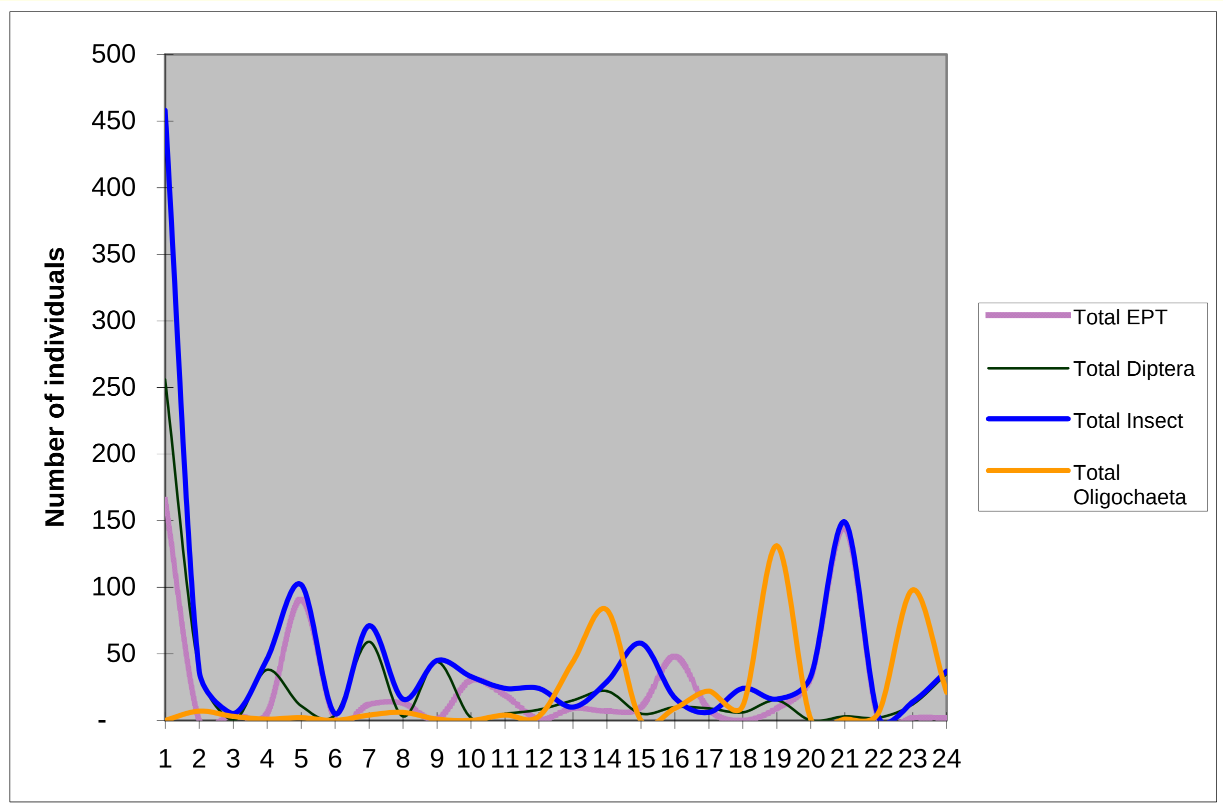

Fig. 6: Comparison of distribution between the Oligochates class (represented only by the Tubicifida order) and the Insect class in the sample population

The Spearman test between the families identified in the local area of King Salmon and the ones found in and around the Refuge indicate that theses two sample populations are not significantly correlated (r(s) = 0.189; p-value = 0.518). An illustration of taxa represented by more than 3 specimens for both data sets (Fig.7) reflects a net difference in the overall community composition defining thus two different populations with three dominant taxa.

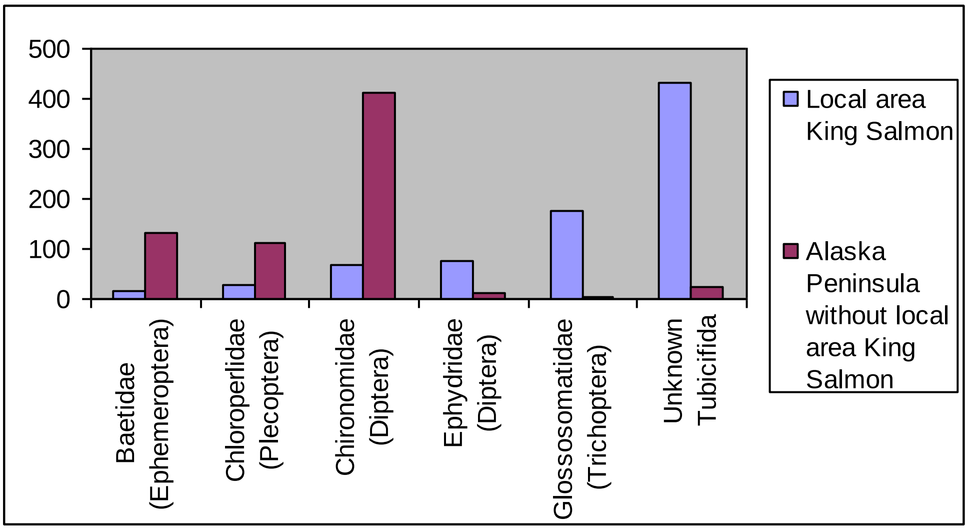

Fig. 7: Assemblages of the main orders present in both study areas of King Salmon and Alaska Peninsula Refuge (only the orders which include at least 3 specimens in one of both areas have been represented)

There is no evidence of significant Spearman correlation between Plecoptera and Ephemeroptera or Plecoptera and Trichoptera but when apply to Ephemeroptera and Trichoptera the Spearman test describe a strong negative correlation (r(s) = -0.605) at a significant level (p-value = 0.037). This is illustrated by the graphical output of the EPT relative composition in the samples sorted by date (Fig. 8).

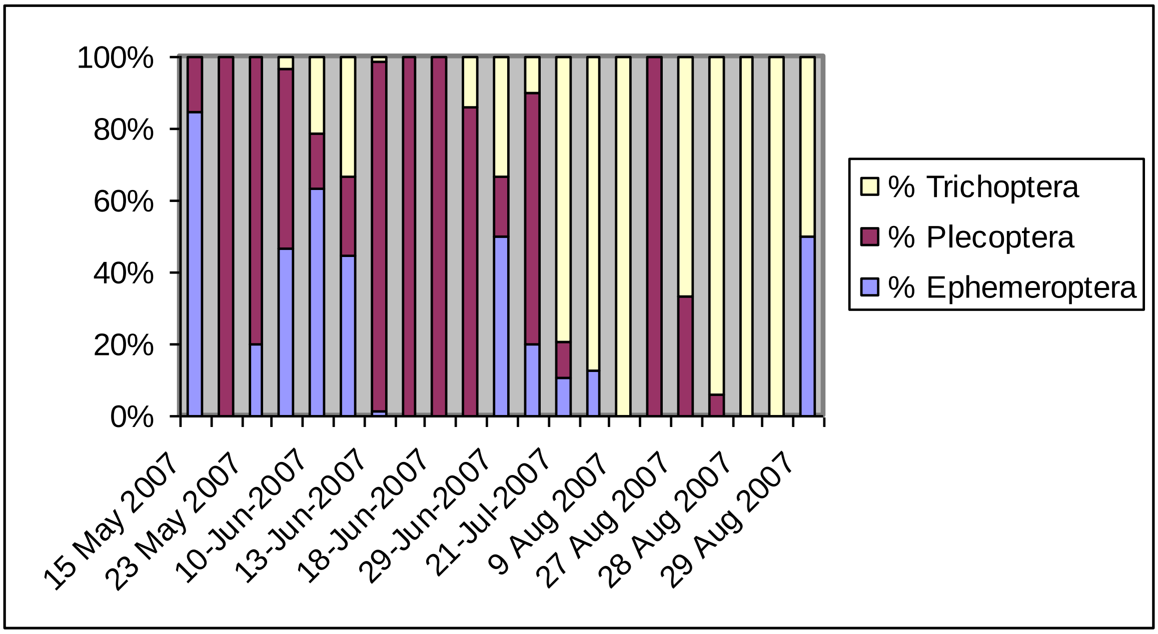

Fig. 8: Relative composition in Ephemeroptera, Plecoptera and Trichoptera orders in relation with the sampling date (the distribution have been restricted to the samples which contain theses taxa in relative proportion ≥2%)

In the Principal Components Analysis (PCA) performed of the covariance matrix the first principal component has variance (eigenvalue) 4.8013 and accounts for 30.0% of the total variance. The second principal component has variance 2.4376 and accounts for 15.2% of the data variability. The scatterplot of the variables (Fig. 9) shows relationships between some taxa and some environmental parameters. The Ephemeroptera, the Chironomidae and the Diptera orders appear to be strongly correlated. A correlation arises between the Trichoptera, the water temperature and the sample date while the pH seems to be anticorrelated (negatively correlated)with them. The stream width and the pH appear to have a low discrimination: no conclusion can be made about its relationship with another variable. No information can be gained from the stream velocity, the substrate and the water mineralization (conductivity). The total of aquatic invertebrates collected is shown to be independent from the pH, the water temperature or the date. For the Plecoptera and Oligochaetes taxa, these orders do not show any relationship with other variables.

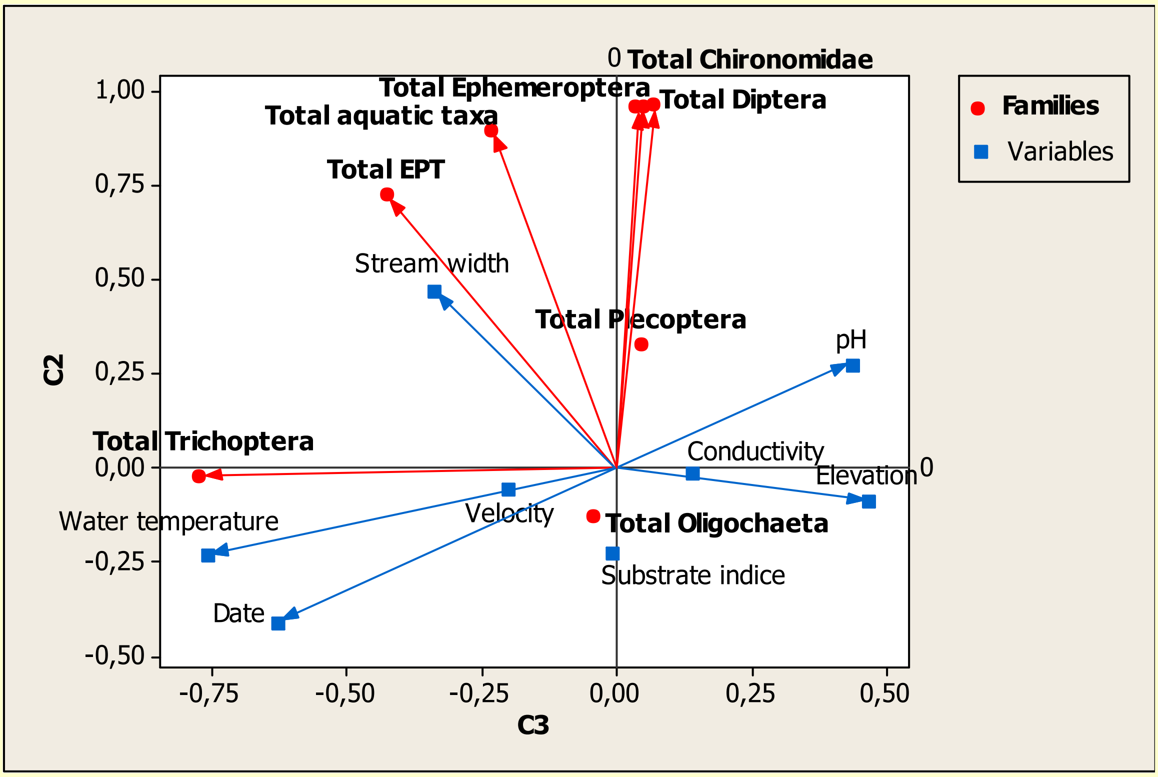

Fig. 9: Correlations between the main invertebrates taxa and the environmental parameters

With a superposition of the sample sites (Fig. 10) no significant group appears but a few relationships may be proposed. Leader Creek, Eskimo Creek, Deer Creek and Ugashik Creek appear to be anti correlated with the Chironomidae, Diptera and Ephemeroptera abundances. More globally it also seems to be a negative correlation with the abundance in EPT and aquatic invertebrates while Kegulik River appears correlated with all of them (unclear, which "All"?). The group of Muddy River, Chignik River, Bear River and Memorial Creek are displayed as anticorrelated with the abundance of Trichoptera, the water temperature and the sample date. But as the different replicates realized in the King Salmon local area appear to be scattered with a large variability within each site (unclear, variable within each site over time for those sampled > 1x?) it seems to be difficult to evaluate how robust are these assumptions for each site.

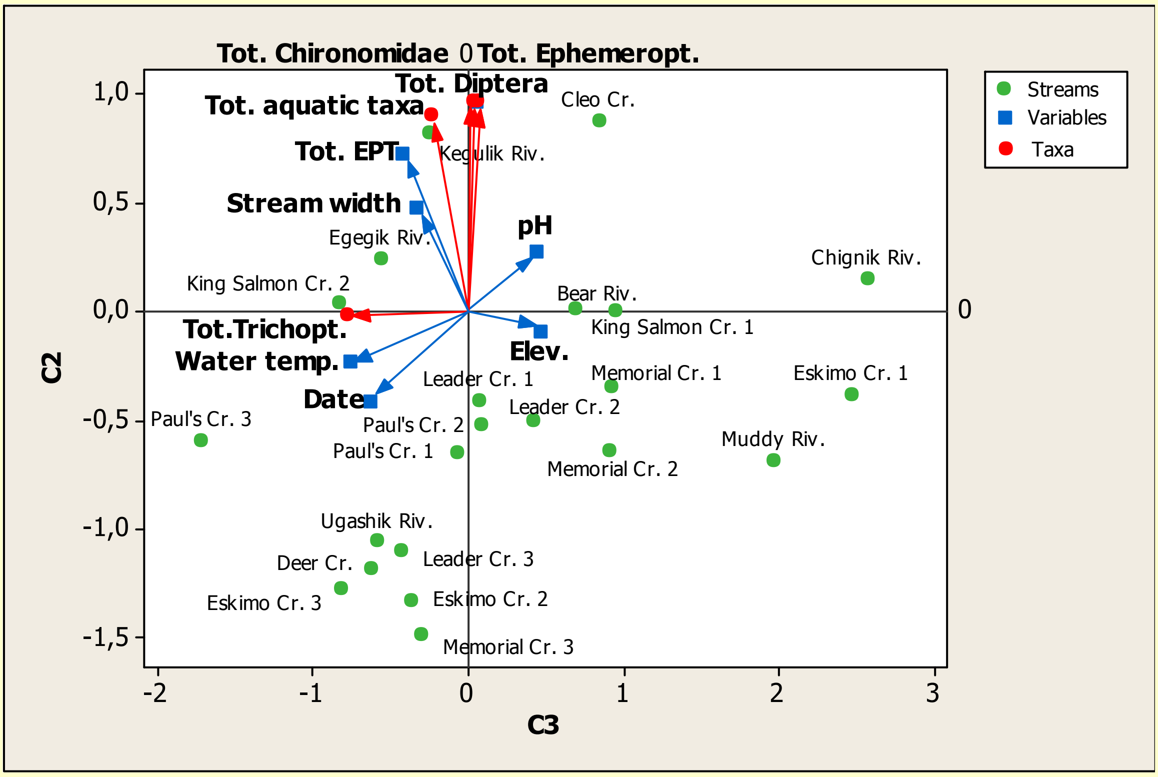

Fig. 10: Correlations between the main invertebrates taxa and the environmental parameters in regard of all sampling sites (King Salmon Creek 3 and Sandy River have been identified as outliers)

III EFFECT OF AN ENVIRONMENTAL GRADIENT ON THE BENTHIC INVERTEBRATES COMMUNAUTIES IN KING SALMON, ALASKA

1. Background

a. Study objectives:

In addition of the qualitative sampling, a semi-quantitative sampling has been conducted in the streams along the 24 km east-west road (situated at approximately 58º44’N) between the towns of King Salmon and Naknek. The purpose was to compare the relative density (and community composition) of benthic macroinvertebrates and to establish a relation with their habitats. Aquatic insects are important in ecosystem-level bio-monitoring both because they are an essential component of most ecosystems and they are sensitive indicators of ecosystem modification (Reice and Wohlenberg, 1993). Therefore biomonitoring information from this survey could be used to detect possible changes in aquatic communities that occur as a result of climate change.
The local area of King Salmon is located currently at the Alaskan southern edge of the boreal forest represented there by the white spruce (*Picea glauca*): the map of the white spruce range in Alaska shows the maximum extent of the spruce-hardwood forests (Fig. 11).

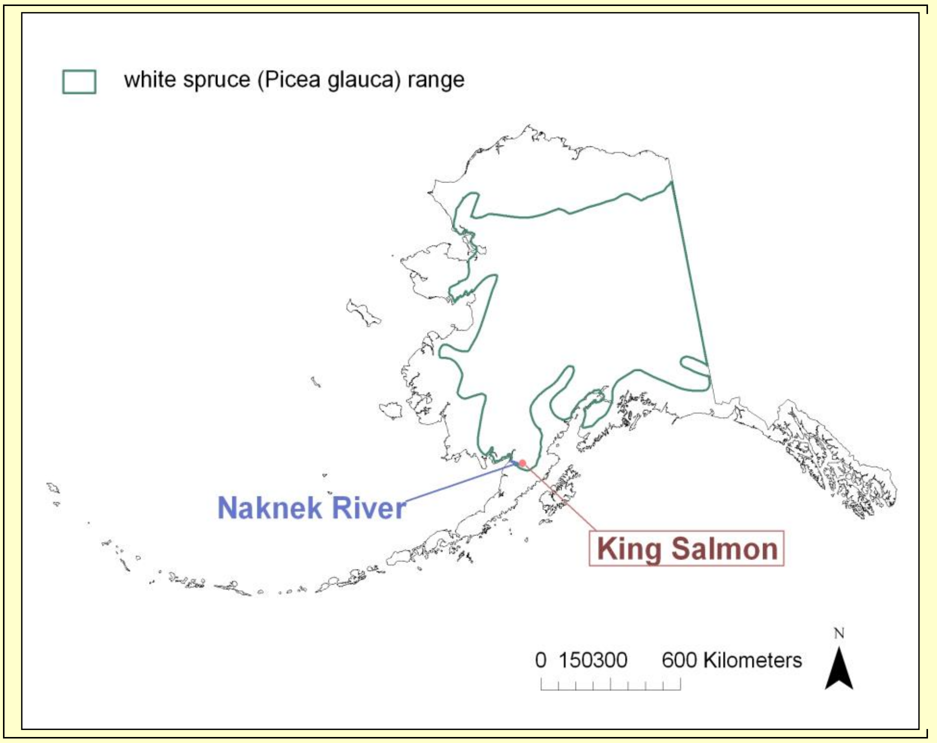

Fig. 11: Range extension of the white spruce (*Picea glauca*) in Alaska (from an illustration in Viereck and Little, 1994)

Two other spruce species are present in the Alaska Peninsula but both have ~~as for the white spruce~~ a range limited to the basis of the Peninsula: the Sitka spruce (*Picea sitchensis*) is only present along the Pacific Coast on the East side while the black spruce (*Picea mariana*) is found further north (Viereck and Little, 1994). This is not the best information about spruce distribution. Too bad you didn't discuss it with me while you were here. By the way, spruce distribution is limited by temperature adequate for reproduction. Westward the boundary between the tundra and boreal-forest stations in Alaska is approximately found midway on the King Salmon-Naknek Highway between Paul's Creek and King Salmon Creek: a longitudinal gradient occurs around King Salmon in addition of a latitudinal gradient. In a consequence the baseline data collected could also be used in the future to assess if changes in community structure would occur due to the range modification of the needleleaf forest as a consequence of climate change. Since climate change is expected to be most noticeable at high latitudes, future comparisons with a baseline would allow interpretation of ongoing changes in a relatively pristine portion of a high latitude region (Talbot *et al.*, 2006).

Stations were sampled during three different time periods in 2007 (in late spring (early summer) – around 20 ~~of~~ June – , in mid-summer – around 20 ~~of~~ July – and late summer – around 20 ~~of~~ August –) so as to encompass seasonal differences in community .structure

b. Study area:

Twelve sites have been selected along five streams in the Naknek River drainage: Eskimo Creek, King Salmon Creek, Memorial Creek, Paul's Creek and Leader Creek (Fig. 12).

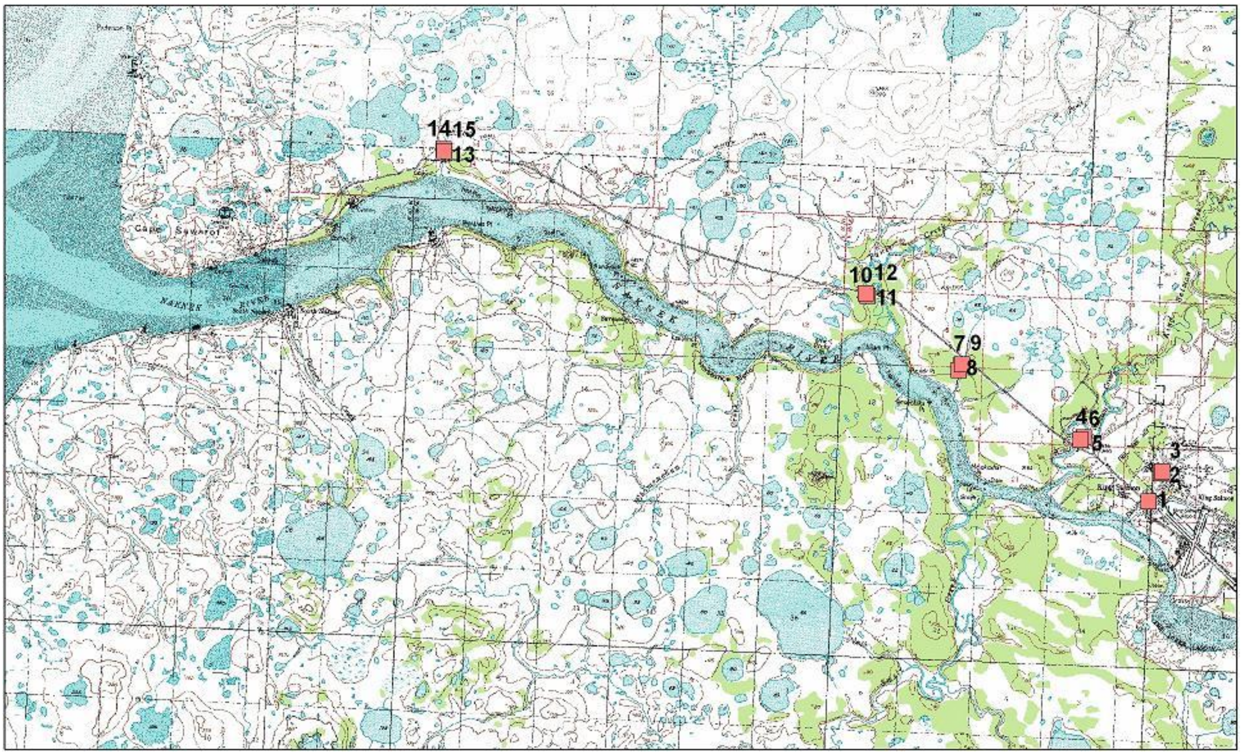

Fig. 12: Location of the macroinverterbrates sampling sites in local streams in King Salmon, Alaska ~~(source: Garmin MapSource©)~~
Sites 1, 2, 3: Eskimo Creek; sites 4, 5, 6: King Salmon Creek; sites 7, 8, 9: Memorial Creek; sites 10, 11, 12: Paul's Creek: sites 13, 14, 15: Leader Creek
The line represents the King Salmon-Naknek Highway.

2. Materials and Methods:

a. Sampling methodology:

The same protocol and materials than for the qualitative sampling has been used. In addition of the stream characteristics recorded in the qualitative survey it has also been recorded information from the habitat using the Alaska Vegetation Classification – AVC- (Viereck *et al*., 1992) on order to determinate an environmental gradient.
Habitat information was collected by adopting the Alaska Landbird Monituring Survey protocol (Handel and Cady, 2004) and typing the major vegetation communities within a 50m-radius circular plot using AVC codes.
Human activities around the stream area appear to be very limited and do not have significantly impacted the riparian zone. That is why hypothesis has been made that human activity surrounding the stream area, if affecting invertebrates populations, do not affect the results as no pollution gradient occurs in the same way of the environmental gradient along the highway.

b. Statistical analysis:

A Kruskal-Wallis test has been realized to provide information about the homogeneity between the triplicates within each site. The hypotheses were:

HO: ŋ1= ŋ2= ŋ3, versus H1: not all ŋ's are equal, where the ŋ's are the population medians.

This test has as purpose to estimate if the different samples collected from June to August ~~during the season~~ could be combined or if ~~a~~ seasonal variability could be detected through the taxa assemblage.

A Spearman rank correlation test has also been performed in order to estimate the reality of an environmental gradient in the stream vegetation between Naknek and King Salmon as well as to establish a relationship between some aquatic invertebrates families and the distance from King Salmon. Sounds like you are taking about vegetation in the stream itself and not the vegetation community surrounding the stream.

3. Results:

The vegetation communities observed for theses five stations are given in Appendix 4. After sorting they have been gathered and converted into formation type (Fig. 13).

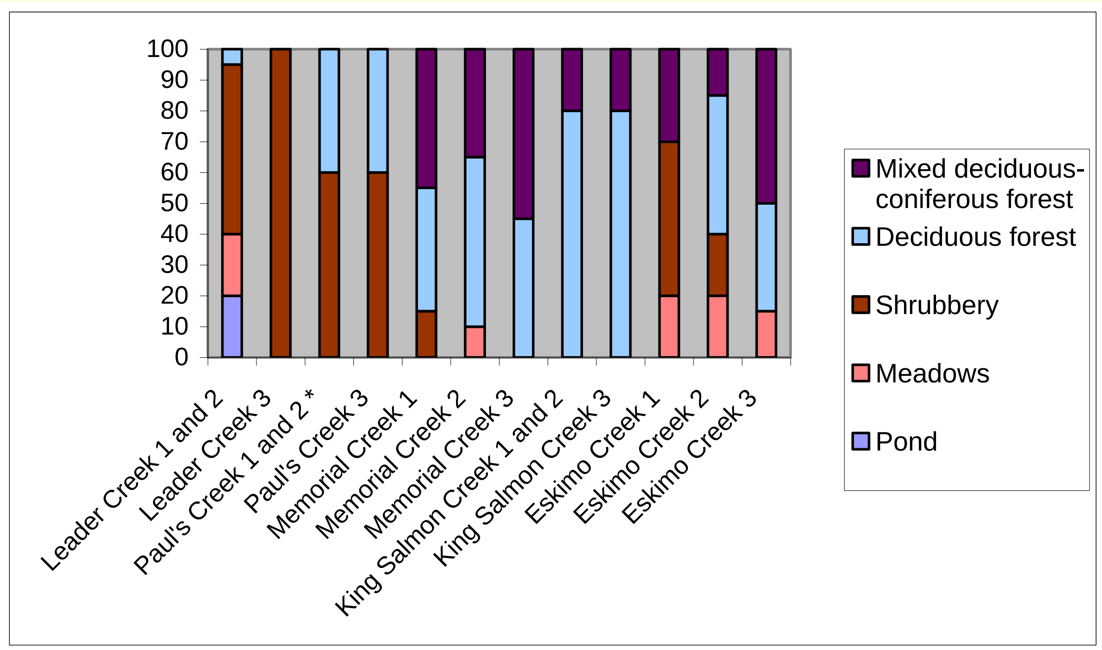

Fig. 13: Vegetation community data for the twelve sites sampled along the King Salmon-Naknek Highway

A Spearman test realized between the type of formation observed indicate no significant correlation ($p>0.05$) between the mixed and the deciduous forest ($r(s) = 0.247$; p-value = 0.438) but a negative correlation between the shrubbery and both deciduous and mixed forest (respectively $r(s) = -0.677$; p-value = 0.016 and $r(s) = -0.800$; p-value = 0.0020) occur. This seems like a trivial statement. Where you have a limited amount of something, if one amount goes up, the other will go down. Maybe it's just the way you are stating it that is unclear. An environmental gradient around the streams can be thus established from Naknek to King Salmon with a vegetal community dominated by shrubs in Naknek area streams and a woodland dominated buffer area for the streams located around King Salmon with an evolution to prevalent mixed forest.

Concerning the reproductibility test within each station the p-values measured are respectably of 0.939 (DF=2) for Eskimo Creek, 0,141 (DF=2) for King Salmon Creek, 0.315 (DF=2) for Memorial Creek, 0.237 (DF=2) for Paul's Creek and 0.681 (DF=2) for Leader Creek. The hypothesis H0 can thus not be accepted at α levels of 0.05: a seasonal variability occurs within each set of replicates.

In the PCA results the distribution of the families (Fig. 14) shows that almost all of them appear to be independent of the distance from King Salmon, unlike the conductivity which appears anticorrelated. Though some seems to be correlated with it: the Tipulidae (crane flies), the Simuliidae larvae (black flies), and the Heptageniidae (flathead mayflies), appear to be more abundant in the streams close to Naknek. No special composition is reflected by this test for the communities located closer to King Salmon. Since an environmental gradient has been established along this highway the differences of composition for theses families and their correlation with the distance from King Salmon could be attributed to this vegetation communities modification. But a large number of taxa, like the Hydrobiidae, the Valvatidae (aquatic snails), the Isopoda (aquatic sow bugs), the Chloroperlidae (green stoneflies), the Baetidae (small minnow mayflies), and the Psephenidae (water pennies), seems to be independent from the distance to King Salmon. The three last ones are displayed with a correlation to the substrate nature. It also can be noted than the Tubificids (aquatic worms) are represented with a relation to the date and the water temperature and an anti correlation with the elevation of the stream.

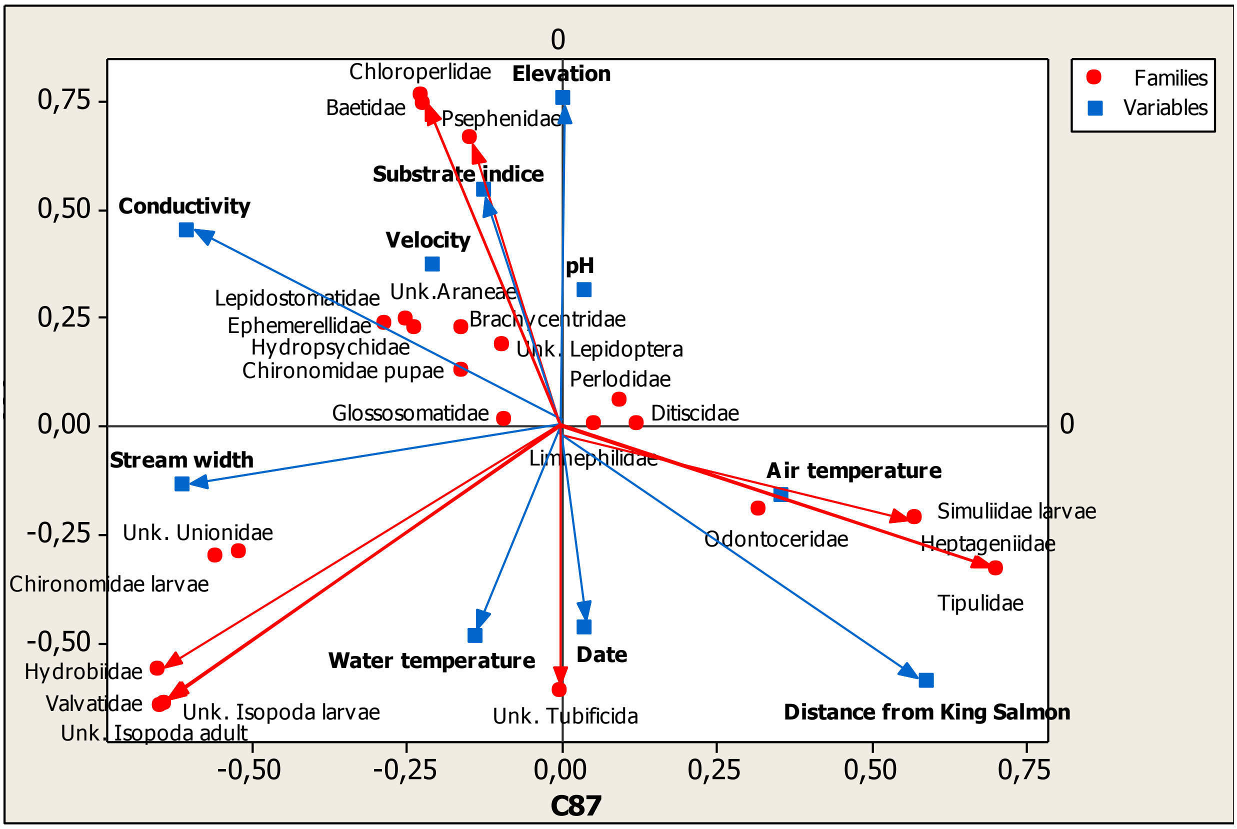

Fig. 14: Correlations between the invertebrates families collected in the local area of King Salmon, the ecological variables and a transect along the Naknek-King Salmon highway (distance from King Salmon)

4. Discussion

This study has yielded valuables baseline information on the benthic invertebrates diversity in streams of the Alaska Peninsula.

The metrics for all these stations include the presence of large numbers of individuals belonging to families with low tolerance ratings, indicating ~~of~~ pristine quality water. Some streams in the King Salmon area may present low abundance in EPT taxa but this may be related to a higher average number of individuals in the samples collected in these streams.

The number of families present in King Salmon streams and not collected in the Refuge and the localization of the maximum size sample collected for each order confirm that the local area of King Salmon is well represented in macroinvertebrates diversity and abundance. (considering you sampled the King Salmon streams more intensely, is this really a fair statement?) Given the Jaccob's Coefficients results, this diversity is more due to a higher α-diversity (intraspecific diversity) in each stream than a β-diversity (interspecific diversity). Community structure of macroinvertebrates between the two areas exhibited different patterns with a predominance of Oligochaetes, caddisflies and crane flies larvae for King Salmon and a prevalence of midges, stoneflies, and mayflies larvae in the Refuge. But this distribution may? not reflects any change in water quality

which could have been generalized to all an area since sensitive pollution taxa (taxa sensitive to pollution?) are found in both areas: what is found there would be more likely due to punctual impaired situations (Leader Creek, Paul's Creek). Further explorations are necessary to determinate the origin of theses situations. Considering management implications the generally high quality conditions of the Naknek River drainage suggest little to no active management should take place to improve water quality or improve in-stream habitat and riparian zone conditions. The abundance and diversity of aquatic invertebrates that utilize Leader Creek or Paul's Creek may always appear low in EPT taxa when compared to other systems. (Note again, these creeks are tidally influenced compared to other creeks you sampled). But with the majority of the stream bed consisting of silt, a suppressed aquatic invertebrate community should be expected and considered a natural condition of these stream systems.
Since each taxon has its own seasonal life cycle (Merritt and Cummins, 1992; Love, 1999) a variance in community assemblage due to the possible seasonal differences could occur as displayed in the relative composition in EPT in relation with the sampling date. In contrary (contrast?) results from the PCA show that the Trichoptera order is the only one affected by the sample date. However due to the size of sample population the hypothesis of an influence of the date on the overall macroinvertebrates assemblage can not be rejected.

No diversity indices (e.g., Shannon's Index) have been calculated since they generally require species-level identifications.
A healthy and stable assemblage is considered to be relatively consistent in its proportional representation, though individual abundances may vary in magnitude (Merritt and Cummins, 1994). Therefore no representation of absolute abundance between sites has been established.
This study confirmed that differences in the structure and abundance of the macroinvertebrate community exist as a result of differences in environmental parameters. But the results did not identify any clear-cut relationships with the vegetation for a large number of families: it is more likely both vegetation and substrate nature that appear to be the main parameters influencing the biotic distribution in the streams. From the analysis performed to date it has not been possible to determine if futures changes in the vegetation would be correlated with significant changes in macroinvertebrate fauna distribution, although possible relationships may exist between biotic distributions and vegetation gradient. A larger sample would be needed to strengthen the hypothesis that the continuing community differences observed are not influenced by differences in physical features, including gradient, stream size, water velocity, and scour patterns in the different sites.

Fundamental to conserving and managing Alaska's aquatic resources is having sufficient baseline and time-series data. However, a persistent problem is that too few baseline and time-series data exist for most aquatic resources in Alaska. No statewide inventory and monitoring program currently occurs to collect aquatic invertebrate data. Substantially different sampling techniques have been used in Alaska to collect benthic macroinvertebrates and effort has been made in different locations to provide a standardized protocol for benthic macroinvertebrates sampling but the specificity of each survey require local adaptations in regard of the amount of effort, the staff and the equipment available. Nevertheless, as proposed by Barbour, results of the different sampling programs in Alaska should be combined into one statewide data set from which to draw information.

Although aquatic invertebrates are not the typical charismatic megafauna natural resources managers focus on, they are an integral component of the diversity of ecosystems and as such are indicators of the healthy functioning of the entire ecosystem. As described in the Ecosystem and Landscape Management Policies of the Comprehensive Conservation Plan, inventorying, monitoring, and maintaining a comprehensive database of selected ecosystem components is critical for making refuge managements decisions and for ensuring the proper long-term stewardship of refuge ecosystem. For this purpose the U.S. Fish and Wildlife Service will employ ecosystem-management techniques to identify species to use as indicators of the health of the ecosystem. (Reference?) But the Refuge has been established by the U.S. Congress in 1980: no significant management activities have occurred before this time and ~~a~~ limited baseline biological data is available. Within limited staff and budgets, the Refuge is mandated to protect and preserve wildlife populations including large mammals, migratory birds, salmonids. For this reason at a short term it will be difficult to add aquatic invertebrates to the inventory and monitoring surveys in progress. This would depend on staff availability and funding.

Although many people think of Alaska as an untouched wilderness—the last frontier—Alaska is not immune to contaminant issues affecting trust resources (i.e., those resources for which the U.S. Fish and Wildlife Service has primary jurisdiction). Several potentially contaminated areas exist on the Refuge. Some of these areas have documented contaminant issues with oil exploration sites and mining sites, and cleanups have occurred in some areas. But little data exist for establishing contaminant baseline levels on the Refuge (Parson, 2004).

Currently, there is no oil or gas development on the Refuge. Additionally, there is no offshore oil and gas development off the coast of the Refuge and no on-shore support facilities. However, oil and gas development on the outer continental shelf of the Bristol Bay lowlands is a potential future issue as President Bush has removed the executive ban on offshore drilling in Bristol Bay in January 2007 and oil and gas leasing may be allowed in Refuge areas with a Comprehensive Conservation Plan amendment. In the same order (Similarly) mineral leasing is prohibited on refuge land but may be allowed on recommendation of the president in specific cases of national need.

Large projects like the proposed Peeble (Pebble) Mine situated 100 miles(=160 kilometers) northeast of King Salmon are already in development in the Bristol Bay. According to Renewable Resources Coalition, which gathers commercial fishermen, natives and sportsmen against mining operations and oils and gas drilling, one of the largest open pit mine in the world is intended by a Canadian company, Northern Dynasty Minerals, to prospect metallic sulphide, copper and gold. The permit applications submitted in September 2006 proposed a nearly 2 miles(=3,2 km) large and 1,500 feet(=460 m) deep mine and a 700 feet(=210 m) tall and 4,3 miles(=6,4 km) long earth dam, which make it the largest in the world. More than 1,000 square miles of additional mining claims are staked throughout Bristol Bay's headwaters with a large potential impact on water quality within state lands. In this perspective baseline data would be helpful in assessing the impacts from potential contamination events in water and biota on and near the Refuge. (You seem to be off point a bit in this section, like you are filling space.) Invertebrates composition measures in freshwater ecosystems serve to help identify potential cause for changes in biotic communities, as well as serve as indicator of changing water conditions themselves. The use of sentinel organisms to environmental stress provides a number of advantages over the direct, chemical analysis of contaminants in water or sediments. For example, this approach can provides a time-integrated indication that the contaminant is "bioavailable", and can warn that other parts of the food web of the ecosystem and the ecosystem may be affected (Johnson et al. 1993). Aquatic insects have been used as sentinel organisms but other, larger freshwater macroinvertebrates are more commonly selected. An expansion of the water quality monitoring within the Refuge including chemical and physical measures, as well as the biotic measure will help to identify and document any future declines in water quality and to develop financial estimates for damage to the aquatic resources, if they occur.

Needs for further studies

- An effort might be made to record more accurately the physical (flow velocity) and chemical (pH) characteristics of the stream, as well as gaining information on dissolved oxygen, although a more accurate measure of the stream velocity may not be very useful as such a measure is very dependant on weather conditions, This takes a huge effort. We are doing this at Becharof outlet (just the physical) and the equipment, staffing, and cost of logistics is quite expensive. You should investigate the cost of equipment and staffing before you go throwing out recommendations. Your experience this summer should give you an appreciation for the difficulty of doing this. Your report itself would benefit from a cost analysis.
- A more precise level of estimated substrate composition might be recorded, with the following categories: - fines (<0.25 cm) (<0.1in.), gravel (0.25-0.8 cm) (0.1-2 in.), cobble (0.8-25 cm) (2-10 in.), boulder (>25 cm) (>10 in.) and bedrock (solid) (3) - and noting their relative abundance in percentage (Oswood, 2004), and it would be benefit to record the gradient, even at a qualitative level (steep, moderate, low),
- In addition an effort might be necessary in the identification with the acquisition of observation material (?your meaning is unclear) in order to get a more precise identification level. The genus level may be appropriate since the species level tends to

be inexact because of the lack of species-level identification keys for the aquatic larvae (Merritt and Cummins, 1996).

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Appendix 1: Pollution Tolerance Levels Values per Taxonomic Group

(Source?)

Taxa	Pollution Tolerance Level
Ephemeroptera	Sensitive (3)
Plecoptera	Sensitive (3)
Trichoptera	Sensitive (3)
Diptera	High Tolerant (1)
Coleoptera	High Tolerant (1)
Oligochaeta	Wide Range Tolerance (2)
Mollusca (right-handed snails)	High Tolerant (1)
Mollusca (left-handed snails)	Sensitive (3)

If one group is not clearly in a category, it must be placed in the "Wide Range Tolerance" Level.

Appendix 2: Taxa and abundance in the Alaska Peninsula sample population

Sandy River samples should be divided into two samples, those done by cabin and those done on 5/21 on upper Sandy River.

Order	Family	Stage	Sandy River	Bear River	Muddy River	Chignik River	Kegulik River	Ugashik River	Cleo Creek	Deer Creek	Egegik River	Eskimo Creek 1	King Salmon Creek 1	Memorial Creek 1	Paul's Creek 1	Leader Creek 1	Eskimo Creek 2	King Salmon Creek 2	Memorial Creek 2	Paul's Creek 2	Leader Creek 2	Eskimo Creek 3	King Salmon Creek 3	Memorial Creek 3	Paul's Creek 3	Leader Creek 3
Ephemeroptera	Baetidae	nymph	128	0	0	1	10	0	0	0	0	1	0	4	2	4	1	0	0	0	0	0	0	0	0	0
Ephemeroptera	Ephemerellidae	nymph	4	0	0	0	2	12	4	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	Heptageniidae	nymph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ephemeroptera	Unknown	nymph	8	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Plecoptera	Chloroperlidae	nymph	21	0	0	4	15	3	2	1	0	85	0	2	3	1	0	0	0	0	1	2	0	0	0	0
Plecoptera	Nemouridae	nymph	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plecoptera	Perlodidae	nymph	0	0	0	0	0	0	0	0	6	0	1	0	4	4	0	0	0	0	0	0	0	0	0	0
Plecoptera	Unknown	nymph	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Plecoptera	Unknown	subadult	0	0	5	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Glossosomatidae	larvae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	28	145	0	2	0
Trichoptera	Lepidostomatidae	larvae	0	0	0	0	1	3	3	0	0	1	0	0	1	37	0	0	3	2	0	0	0	0	0	0
Trichoptera	Odontoceridae	larvae	0	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0	3	2	0	0	0	0	0	0
Trichoptera	Hydropsychidae	larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Trichoptera	Limnephilidae	larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
Trichoptera	Brachycentridae	larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	2	0	0	0	0
Trichoptera	Unknown	larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Diptera	Chironomidae	larvae	180	38	0	23	2	4	10	7	2	5	0	59	4	8	8	6	3	1	44	0	1	0	11	0
Diptera	Chironomidae	pupae	44	0	0	14	0	0	2	0	0	5	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Diptera	Simuliidae	pupae	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Simuliidae	larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Diptera	Ephydridae	larvae	5	0	0	1	0	1	3	0	19	1	4	0	0	1	1	0	12	2	0	0	2	2	1	34
Diptera	Unknown	pupae	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Ditiscidae	adult	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Psephenidae	larvae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidoptera	Unknown	larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Tubificida	Unknown	adult	0	7	3	1	0	4	44	3	83	2	0	4	0	9	22	11	131	6	1	1	1	6	98	21
Unionidae	Unknown	adult	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	2	0
Araneae	Unknown	adult	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
Isopoda	Unknown	adult	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0
Isopoda	Unknown	larvae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0
Neotaenioglossa	Hydrobiidae	adult	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0
Ectobranchia	Valvatidae	adult	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0

Appendix 3: Matrix of calculated Jaccard's Coefficients for each site

	Sandy River	Bear River	Muddy River	Chignik River	Kegulik River	Ugashik River	Cleo Creek	Deer Creek	Egegik River	Eskimo Creek	King Salmon Creek	Memorial Creek	Paul's Creek	Leader Creek
Sandy River	-													
Bear River	0,14	-												
Muddy River	0	0,50	-											
Chignik River	0,43	0,40	0,20	-										
Kegulik River	0,44	0,17	0	0,29	-									
Ugashik River	0,40	0,25	0,11	0,44	0,40	-								
Cleo Creek	0,40	0,22	0,13	0,44	0,40	0,56	-							
Deer Creek	0,20	0,40	0,20	0,33	0,22	0,30	0,44	-						
Egegik River	0,20	0,40	0,20	0,43	0,10	0,30	0,30	0,25	-					
Eskimo Creek	0,29	0,20	0,08	0,45	0,29	0,43	0,43	0,23	0,21	-				
King Salmon Creek	0,18	0,33	0,17	0,38	0,09	0,56	0,27	0,22	0,57	0,29	-			
Memorial Creek	0,45	0,22	0,11	0,56	0,56	0,80	0,64	0,30	0,40	0,40	0,36	-		
Paul's Creek	0,29	0,14	0,07	0,25	0,25	0,47	0,43	0,20	0,36	0,53	0,43	0,53	-	
Leader Creek	0,45	0,18	0,09	0,44	0,44	0,31	0,50	0,25	0,33	0,44	0,31	0,43	0,39	-

In yellow: comparison between streams of the refuge area;
in blue: comparison between streams of the King Salmon area;
in orange: comparison between both areas streams

Appendix 4: Vegetation structure (percentage) of the riparian zone in the sampling sites of the King Salmon area per AVC type

Site	% of circle	Viereck Class	Dominant Species
Leader Creek 1 and 2	55	CTS	Salix planifolia, Salix barclayi
	20	MGH	Calamagrostis canadensis
	5	CBF	Betula kenaica
	20	Pond	
Leader Creek 3	100	CTS	Betula kenaica, Salix planifolia, Alnus sinuata
Paul's Creek 1 and 2 *	60	OTS	Betula kenaica
	40	CBF	Betula kenaica, Alnus sinuata
Paul's Creek 3	60	OTS	Betula kenaica
	40	CBF	Betula kenaica, Alnus sinuata
Memorial Creek 1	45	CMF	Betula kenaica, Picea glauca
	40	OTS	Betula nana
	15	MGH	Calamagrostis canadensis
Memorial Creek 2	55	OBF	Betula kenaica
	35	CMF	Betula kenaica, Picea glauca
	10	MGH	Calamagrostis canadensis
Memorial Creek 3	55	CMF	Betula kenaica, Picea glauca
	45	OBF	Betula kenaica
King Salmon Creek 1 and 2	80	CBF	Alnus sinuata, Betula kenaica
	20	OMF	Betula kenaica, Picea glauca
King Salmon Creek 3	80	CBF	Alnus sinuata, Betula kenaica
	20	OMF	Betula kenaica, Picea glauca
Eskimo Creek 1	50	OTS	Salix barclayi
	30	OMF	Betula kenaica, Picea glauca
	20	MGH	Calamagrostis canadensis
Eskimo Creek 2	45	OLS	Salix planifolia
	20	MGH	Carex sp.
	20	EDS	Empetrum nigrum
	15	OMF	Picea glauca
Eskimo Creek 3	50	OMF	Alnus sinuata, Picea glauca
	35	OLS	Salix planifolia
	15	WGH	Carex sp.

Appendix 5: Vegetation structure (percentage) of the riparian zone in the sampling sites of the King Salmon area per vegetal formation

	Leader Creek 1 and 2	Leader Creek 3	Paul's Creek 1 and 2	Paul's Creek 3	Memorial Creek 1	Memorial Creek 2	Memorial Creek 3	King Salmon Creek 1 and 2	King Salmon Creek 3	Eskimo Creek 1	Eskimo Creek 2	Eskimo Creek 3
CTS	55	100										
MGH	20					10				20	20	
CBF	5		40	40	40			80	80			
Pond	20											
OTS			60	60	15					50		
OMF								20	20	30	15	50
CMF					45	35	55					
OBF						55	45					
OLS											45	35
EDS											20	
WGH												15

	Leader Creek 1 and 2	Leader Creek 3	Paul's Creek 1 and 2	Paul's Creek 3	Memorial Creek 1	Memorial Creek 2	Memorial Creek 3	King Salmon Creek 1 and 2	King Salmon Creek 3	Eskimo Creek 1	Eskimo Creek 2	Eskimo Creek 3
Pond	20											
Meadows	20					10				20	20	15
Shrubbery	55	100	60	60	15					50	20	
Deciduous forest	5		40	40	40	55	45	80	80		45	35
Mixed deciduous-coniferous forest					45	35	55	20	20	30	15	50

ABSTRACT
A total of 110 benthic samples were collected from fourteen streams in southwest Alaska from May to August 2007. There were two objectives in this study. The first was to determinate which taxa are present in the Alaska Peninsula. For this objective sampling was conducted in the Alaska Peninsula and Becharof National Wildlife Refuge area through (during) several inventory and monitoring projects as well as in the streams around King Salmon. The 2007 study could be the first stage in developing an aquatic invertebrate~~s~~ inventory within the Refuge, followed by periodic trend monitoring.
The second objective was to evaluate correlations between environmental parameters measured (vegetation) and macroinvertebrate fauna distribution in the King Salmon area streams. The main hypothesis for this objective was that a difference in the diversity of aquatic macroinvertebrates fauna occurs significantly along a gradient of vegetal formations in the riparian zone.
For both studies individuals were identified by the primary author mostly at a family level. Results from the fourteen stations indicate~~s~~ that the overall macroinvertebrate community structure showed different patterns between King Salmon and Refuge areas and demonstrates some relationships between taxa and environmental parameters. Results of the King Salmon area data set show significant correlations between the structure of the macroinvertebrate community and both riparian vegetation and stream substrate nature. It also appears with this data set that the Simuliidae (black flies) larvae, the Tipulidae (crane flies), and the Heptageniidae (flathead mayflies) abundances seem to be correlated with a climatic and vegetal gradient. This can be used in the future to compare against possible changes in the biotic distribution due to climate change.

RESUME
110 échantillons d'invertébrés aquatiques on été récoltés dans 14 différents cours d'eau du sud-est de l'Alaska de mai à août 2007. Le premier objective était de déterminer le nombre de taxons présents à l'intérieur de la Péninsule d'Alaska. Cette étude pilote, réalisée dans et autour de la réserve nationale de Becharof et de la Péninsule d'Alaska, pourrait déboucher à l'avenir à moyen terme sur un programme d'inventaire dans la réserve. Le second objectif était d'étudier les relations entre la structure de la population d'invertébrés aquatiques et des variables environnementales comme la végétation.
Les résultats mettent en évidence une différence entre les échantillons récoltés autour de King Salmon et ceux de la réserve. De même on observe une évolution précise dans la composition de la population dans la région de King Salmon en fonction de la nature du substrat et de la composition de la végétation riveraine : les larves de Simulidés (mouches noires), de Tipulidés (cousins) et d'Heptageniidés (éphémères) apparaissent plus abondants avec une végétation composée de forêts de conifères. Ces données pourront être utiles pour comparer de possibles changements dans la composition

biotique suite à un retrait vers le nord de la forêt boréale avec le réchauffement climatique.